III. The Loss of Soil Management Subsidies: An Application

Tables 1 to 6 contain the estimates of the equations of this model.[14] The first preference was to estimate the production function (equation A.1) and the transition equation for soil, and then use those estimates to derive the other relationships in the model. However, severe multicollinearity in the inputs and soil management data[15] made it impossible to obtain reliable estimates of the parameters of the production function. To overcome this problem the model was estimated at the level of the first-order necessary conditions (Euler equations) for the optimization of the farmer's problem (that is, manipulations of equations A.2 and A.3).

Consider first the derivation from the first order condition with respect to inputs (table 1). This can be construed as the derived demand curve for inputs. The estimates indicate that input demand is positively related to soil management lagged one period (SM in the table) and soil depth (SOILD in the table). Recall that soil management has a one-year lagged effect. Thus, farmers who enhance their soils productivity (by rotation) complement the productivity effect by using more inputs. The same holds for soil depth. Surprisingly, there was also a positive relationship between real relative input prices (INPRI) and inputs used. The estimated equation explains the majority of the variance in input usage, and the marginal significance of 0.87 for the Box-

Pierce Q statistic suggests that there is little evidence of residual correlation.

Estimates of the Euler equation that comes from the first order condition with respect to soil management are reported in table 2A. As before, we have the complementary effect between soil management and inputs. The estimates also show a negative relationship between soil management and soil depth the next period. Farmers compensate for shallow soil by increasing soil management. As would be expected, government subsidies for soil management (ACP) increase the demand for it. Although these estimates explain over 80% of the variation in soil management there is marginal evidence of serial correlation in the errors. Table 2B corrects for the serially correlated errors. All signs are maintained, and the explanatory power of the equation is increased.

Of the three structural equations estimated, the soil transition equation (table 3A) is the least satisfactory. While the estimates of d_1 and d_2 are reasonable, there is strong evidence of serial correlation in the errors of this equation. The serial correlation is corrected in table 3B. Again, there is improvement in the estimates from this correction.

In pursuing the time consistent strategy in attempting to minimize (2), the ASCS presumably "looked at everything." Thus, an estimate of the policy rule followed by the Service during the sample can be obtained by regressing S_t (ACP) on all of the variables that appear in the structural equations and were available at the time the subsidy was set. This estimate is given in table 4. It explains virtually all of the variation in S_t, and the remaining errors are not serially correlated. This estimation is more useful for forecasting than understanding the structural behavior of the ASCS.

An alternative estimate is given in table 5A, which is the consistent decision rule for subsidies which is optimal for minimizing (2), assuming $S^*_t = S_{t-1}$.[16] There is strong evidence of serially correlated errors[17]. In Table 5B the serial correlation is corrected. The estimates in table 5B, along with those from tables 1 to 3, imply that h=2.065.

The final equation for which an estimate is needed is (6), that is $R_t=A^*(L)u_t$. Three procedures were used for analyzing this relationship. First, autoregressive models of several lags were estimated using OLS. Only one of these estimations, an AR(1) with no constant produced a significant estimate for a coefficient. However, this equation had a poor fit. A chi-square test (table 6A)[18] found a significance level of 0.93, indicating no serial correlation. All indications were that R_t follows a white noise. To check this, as reported in table 6B, autocorrelations for six lags were computed. Using the test statistic

$$z = \frac{(n-3)^{.5}}{2} \ln \frac{(1+r_k)(1-r^*_k)}{(1-r_k)(1+r^*_k)}$$

which is approximately normal (see Freund, p.381), the estimated correlation r_k was tested against the value $r^*_k=0$ for $k = 1,2,...6$. For all k the null hypothesis that $r_k=0$ could not be rejected, and therefore we take R_t to be white noise, that is, $R_t=u_t+R^*$, where R^* is the central (mean) value and $A^*(L)=1$.[19]

Using the estimates discussed above it is easily derived by substitution that (in equation A.6) $K_1=.201$, $K_2=0.001$, $K_3=.412$, $p=1.002$ and $m=0.963$. It is now possible to derive the optimal precommitment rule, using these values, $h=2.065$ and $A(z)=1$ in (11) or (13). Then it will be possible to compare the actual SCS subsidy rules to the optimal one, and derive measures of regulatory loss.

Two measures are used to compare the optimal system to the actual one. First, we examine how each system responds to shocks. To do this, the covariance structure estimated in the system equations was imposed on the optimal and estimated models and we calculated the response of each system to shocks in soil management, soil depth, and government subsidy (ACP). These are presented in Figures 1 through 3. Each figure shows the movement of soil management, soil depth and subsidy under the optimal rule and the actual rule. Figure 1 shows system responses to a shock in soil management, figure 2 is for a shock in soil depth, and figure three is for a shock in ACP (subsidy).

Generally, both systems show the same patterns of responses to shocks, although the optimal system's responses are stronger. (In all plots the first two periods are eliminated for better scaling of the figure). When soil management suffers a (positive) shock (Figure 1) ACP and soil management move towards the initial values (but show a persistent but seemingly stable increase) while soil depth in both systems steadily increases. However, the optimal system moves back towards the initial values faster (for ACP and soil management) and has a stronger increase in soil depth.

A similar pattern holds for shocks to soil depth (Figure 2), although here the effect on soil depth is the about the same for the optimal system and the actual system. The actual system shows a stronger continued growth in soil depth than the optimal one, but also has a stronger persistance in the increase of ACP and soil management.

The real difference is in the response of the systems to a shock in ACP (Figure 3). While there are initial fluctuations in both systems, the optimal system moves towards the initial values, and stabilizes at slight increases in all variables. For the actual system recovery is not as complete for soil management and ACP, and there is a strong (positive) response of soil depth.[20]

A second comparison was made using simulations of the two models. The paths were simulated by using the actual values of INPRI, and solving for the endogenous variables in the models. These are reported in tables 7 through 9 and figures 4 to 7.

For soil management and ACP, the optimal system was somewhat more volatile than the actual one, and although the patterns were similar. Soil depth showed strong persistence. Soil management, ACP and soil depth were also consistently higher for the optimal system.

Of primary interest are the simulated values for soil management. Discussions with SCS staff indicate that a potato, oats rotation (yearly) is considered optimal for the area generating this data (giving an M*=2). We see that the optimal. rule fluctuates around a mean of 2.2, while the actual rule was centered around 1.5 (about a potato, potato, oats rotation). This means under the optimal rule, the average soil management would <u>exceed</u> the "T" value, causing an increase in soil depth, as shown in figure 6.

From a regulatory perspective, the key value is that of the objective function. These are given in table 9 and figure 7. A lower value is better and, most interestingly, the optimal rule is not completely dominant over the actual rule in meeting the policymaker's objectives. The values of the objective function were initially greater under the optimal rule, although for remaining 17 of the 23 years calculated, the optimal rule was better. It is clear that there are opportunities for policymakers to extract <u>large</u> short-term gains by using something other than the optimal rule. Initially, the actual rule obtained large benefits. But as the farmers caught on, they changed their expectations, and the value of the objective function increased. By the sixth period the optimal rule becomes better, and remains so. What has happened is that the system evolved to a consistent but <u>not optimal</u> rule. Overall and on average, the optimal rule is better. The average value of the objective function with the optimal rule was 0.252899, while with the actual rule the average value was 0.284950, an improvement of about 13 percent.

IV. Conclusions

The question remains that if the proposed rule is so good, why doesn't the SCS follow something like it? The argument here is that the decision makers are pursuing short-term benefits at the expense of long-term gains. Even if the ASCS promises not to do so in the future, intelligent farmers see the repeated series of actions, and formulate expectations based on the short-term policies. The policymaker responds to the farmers, and the system evolves. By not precommiting at the beginning, the ASCS has relinquished its ability to exploit expectations. This is <u>not</u> because it is stupid, but probably because it operates in a (political) short-run. The appeal of short-term benefits from its policy actions is too great. Essentially, the problem is discretion, and the solution is to remove it.

There are, of course, alternative explanations for why the ASCS does not follow the optimal rule. One which is foremost is that the objective function used in this analysis is not the correct one. That is, despite its rhetoric, the goal of government policymakers may <u>not</u> be to hit the T. If so, then two parts of this paper are of primary importance: first that the ASCS must understand how farmers' reactions and expectations matter (whatever the objective), and second that the optimal rule for achieving "T" erosion can be used as a norm of physical costs, to differentiate from economic costs of soil loss. But if the stated objectives ("T" erosion) of the program are not those actually pursued then complete policy analysis requires a model of ASCS rent seeking, something that lies beyond the bounds of this paper. Here we provide the best rule for a specific goal, hitting the "T", and in any case the analysis gives measures of how actual ASCS behavior misses it.

APPENDIX A

MATHEMATICAL DERIVATIONS

I. Derivation of Equation (7):

Let

$$(A.1) \quad Y_t = a, + a_1 D_t + a_2 X_t + a_3 M_{t-1} + a_4 X_t^2 + a_5 D_t^2 + a_6 M_{t-1}^2 + a_7 X_t M_{t-1} + a_8 X_t D_t + a_9 D_t M_{t-1}.$$

This is taken as a quadratic (Taylor) approximation of the true production function. Soil management, that is crop rotation and/or fallow land, has a one year lag an productivity. After substituting (A.1) into (4) the first order necessary conditions for the farmer's optimization problem (ignoring (5)) are

$$(A.2) \quad E_{t-1}[a_2 + 2a_4 X_t + a_7 M_{t-1} + a_8 D_t - R_{t-1}] = 0$$

from the partial derivative with respect to X_t and

$$(A.3) \quad E_{t-1}[ba_3 + 2ba_6 M_t + ba_7 X_{t+1} + ba_9(d_1 D_t + d_2 M_t) + S_{t-1}] = 0$$

from the partial derivative with respect to M_t, using the definition of D_{t+1}. Equation (A.2) implies that

$$(A.4) \quad E_{t-1} X_{t+1} = E_{t-1}(1/2a_4)[R_t - a_2 - a_7 M_t - a_8(d_1 D_t + d_2 M_t)]$$

again using the definition of D_{t+1}. Substituting (A.4) into (A.3) and rearranging gives

$$(A.5) \quad G_0 + G_1 E_{t-1} M_t + G_2 E_{t-1} D_t + G_3 E_{t-1} R_t + S_{t-1} = 0$$

where

$$G_0 = ba_3 - [ba_2a_7/2a_4]$$

$$G_1 = 2ba_6 - [(ba_7/2a_4)(a_7 + a_8d_2)] + ba_9d_2$$

$$G_2 = ba_9d_1 - [ba_7a_8d_1/2a_4]$$

$$G_3 = ba_7/2a_4$$

or

(A.6) $E_{t-1}M_t - K_1E_{t-1}D_t = K_2E_{t-1}R_t + K_3S_{t-1} + K_0$

where

$$K_1 = -G_2/G_1$$

$$K_2 = -G_3/G_1$$

$$K_3 = -1/G_1$$

$$K_0 = -G_0/G_1.$$

Using equation (3) in the text we can write

(A.7) $E_{t-1}D_t = (1-d_1L)^{-1}d_2M_{t-1}.$

Substituting (A.7) into (A.6), multiplying both sides by $(1-d_1L)$ and leading the result one period gives (7).

II. Derivation of Equation (12):

Substitute (10) into (9b) to get

$$c(z) = \left\{\frac{d(z)}{1-pz}\right\} \Big\{zA(z) + z(hp+d_1)^{-1}(1-mz)^{-1}(1-m^{-1}z)^{-1}zd(z)d(z^{-1})A(z)$$

$$- z(hp+d_1)^{-1}(1-mz)^{-1}(1-m^{-1}z)^{-1}md(m)d(m^{-1})A(m) - p^{-1}A(p^{-1})$$

$$- p^{-1}(hp+d_1)^{-1}(1-mp^{-1})^{-1}(1-m^{-1}p^{-1})^{-1}p^{-1}d(p^{-1})d(p)A(p^{-1})$$

$$+ p^{-1}(hp+d_1)^{-1}(1-mp^{-1})^{-1}(1-m^{-1}p^{-1})^{-1}md(m)d(m^{-1})A(m)\Big\}.$$

Noting that

$$-(hp+d_1)^{-1}(1-mp^{-1})^{-1}(1-m^{-1}p^{-1})^{-1}p^{-1}d(p^{-1})d(p) = 1$$

and so

$$p(hp+d_1)(1-mp^{-1})(1-m^{-1}p^{-1}) = -d(p)d(p^{-1})$$

(using the fact that $[m+m^{-1}] = [h+hp^2+1+d_1^2]/[hp+d_1]$) we get that

$$\text{(A.8)}\quad c(z) = \left[\frac{d(z)}{1-pz}\right]\left[\left\{\frac{1}{d(z)d(z^{-1})} + \frac{z}{(hp+d_1)(1-mz)(1-m^{-1}z)}\right\}d(z)d(z^{-1})zA(z)\right.$$

$$\left. + \left\{\frac{1}{d(p)d(p^{-1})} + \frac{z}{(hp+d_1)(1-mz)(1-m^{-1}z)}\right\} d(m)d(m^{-1})mA(m)\right].$$

The first term in the braces of (A.8) can be written

$$\left\{\frac{1}{d(z)d(z^{-1})} + \frac{z}{(hp+d_1)(1-mz)(1-m^{-1}z)}\right\} = \frac{(hp+d_1)(1-mz)(1-m^{-1}z)+zd(z)d(z^{-1})}{d(z)d(z^{-1})(hp+d_1)(1-mz)(1-m^{-1}z)}.$$

The numerator reduces to $hp(1-p^{-1}z)(1-pz)$, again using the relationship between $m+m^{-1}$ and h, d_1 and p. Similarly, the second term in braces can be written

$$\frac{hp(1-mz)(1-m^{-1}z) + z\ d(m)d(m^{-1})}{(hp+d_1)(1-mz)(1-m^{-1}z)d(m)d(m^{-1})}$$

using the fact that $d(p)d(p^{-1}) = [(hp+d_1)/hp]d(m)d(m^{-1})$. Again the numerator reduces to $hp(1-p^{-1}z)(1-pz)$. Therefore

$$c(z) = \left\{\frac{d(z)}{1-pz}\right\}\left\{\frac{hp(1-p^{-1}z)(1-pz)zA(z)}{(hp+d_1)(1-mz)(1-m^{-1}z)} + \frac{hp(1-p^{-1}z)(1-pz)mA(m)}{(hp+d_1)(1-mz)(1-m^{-1}z)}\right\}$$

or

$$\text{(A.9)}\quad c(z) = \left\{\frac{d(z)}{1-pz}\right\}\left\{\frac{hp(1-p^{-1}z)(1-pz)}{(hp+d_1)(1-mz)(1-m^{-1}z)}\right\}\{zA(z) - mA(m)\}$$

III. Derivation of Equation (13):

We seek $S_t = B(L)M_t$. Note that $M_t = C(L)u_t$ and $S_t = F(L)u_t$. Therefore $S_t = F(L)C(L)^{-1}M_t$ or $B(z) = F(z)C(z)^{-1}$. Thus

$$B(z) = \left\{\frac{zd(z)d(z^{-1})A(z)-md(m)d(m^{-1})A(m)}{(hp+d_1)(1-mz)(1-m^{-1}z)}\right\} C(z)^{-1}.$$

Using (A.9) this becomes

$$\text{(A.10)}\quad B(z) = \left\{\frac{(hp)^{-1}}{d(z)(1-p^{-1}z)}\right\}\left\{\frac{zd(z)d(z^{-1})A(z)-md(m)d(m^{-1})A(m)}{zA(z) - mA(m)}\right\}.$$

The desired result is obtained by multiplying $S_t = B(L)m_t$ through by $(1-p^{-1}L)$ and expanding the term in the second set of braces in (A.10).

APPENDIX B

Proof of Proposition 2:

When $M_t = C(L)u_t$, the covariance generating function is given by $g_y(z) = C(z)C(z^{-1})$ where C(z) is the z-transform of the coefficients in C(L). The covariance EM_tM_{t-j} is given by the coefficient on z^j in $g_Y(z)$. By using the inversion formula

$$EM_tM_{t-j} = \frac{1}{2\pi i} \oint C(z)C(z^{-1})z^{-j-1}dz$$

where $\oint$ represents contour integration about the unit circle $|z| = 1$. Therefore, the value of the policymakers' objective function (equation 2) in frequency domain notation is

$$J = \frac{1}{2\pi i} \oint \frac{(1-d_1z)[zG(z)-p^{-1}G(p^{-1})](1-d_1z^{-1})[z^{-1}G(z^{-1})-p^{-1}G(p^{-1})]}{(1-pz)(1-pz^{-1})} \frac{dz}{z}$$

$$+ \frac{h}{2\pi i} \oint F(z)F(z^{-1}) \frac{dz}{z}$$

where $G(z) = A(z) + F(z)$. Letting $G^*(z) = (1-d_1z)[zG(z)-p^{-1}G(p^{-1})]$ we can write (B.1) as

$$J = \frac{1}{2\pi i} \oint \frac{[G^*(z)G^*(z^{-1}) + h(1-pz)(1-pz^{-1})F(z)F(z^{-1})}{(1-pz)(1-pz^{-1})z} dz.$$

Note that $\partial G^*(z)/\partial F_j = (1-d_1z)(z^{j+1} - p^{-j-1})$ and obtain the first order conditions for optimizing J by setting $\partial J/\partial F_j = 0$ for $j = 0, 1, \ldots$:

$$0 = \frac{1}{2\pi i} \oint \Big\{(1-d_1 z)z^{j+1}G^*(z^{-1}) + h(1-pz)(1-pz^{-1})z^j F(z^{-1})$$

$$+ (1-d_1 z^{-1})z^{-j-1}G^*(z) + h(1-pz)(1-pz^{-1})z^{-j}F(z)$$

$$- (1-d_1 z)p^{-j-1}G^*(z^{-1})$$

$$- (1-d_1 z^{-1})p^{-j-1}G^*(z)\Big\} \Big\{(1-pz)(1-pz^{-1})z\Big\}^{-1} dz$$

or

$$\frac{1}{2\pi i} \oint [z^j H(z^{-1}) + z^{-j}H(z)] \frac{dz}{z} =$$

(B.2)

$$\frac{p^{-j-1}}{2\pi i} \oint \left\{\frac{(1-d_1 z)(1-d_1 z^{-1})[z^{-1}G(z^{-1})-p^{-1}G(p^{-1})+zG(z)-p^{-1}G(p^{-1})]}{(1-pz)(1-pz^{-1})}\right\} \frac{dz}{z}$$

where $H(z) = (1-d_1 z^{-1})z^{-1}G^*(z)/(1-pz)(1-pz^{-1}) + hF(z)$. The right-hand side of (B.2) is analytic as the closed unit disk everywhere but $z = 0$. ($z = p^{-1}$ is <u>not</u> singularity since it factors out of the numerator). To see this, write the RHS of (B.2) as

$$\frac{p^{-j-1}}{2\pi i} \oint \left\{\frac{(1+d_1^2-d_1 z)\ [z^{-1}G(z^{-1}) - p^{-1}G(p^{-1}) + zG(z) - p^{-1}G(p^{-1})]}{(1-pz)(1-pz^{-1})}\right\}\ z$$

$$- \frac{p^{-j-1}}{2\pi i} d_1 \oint \frac{zG(z)-p^{-1}G(p^{-1})}{z(1-pz)(1-pz^{-1})} \frac{dz}{z} - \frac{p^{-j-1}}{2\pi i} d_1 \oint \frac{z^{-1}G(z^{-1})-p^{-1}G(p^{-1})}{z(1-pz)(1-pz^{-1})} \frac{dz}{z}$$

where we have expanded the $(1-d_1 z)(1-d_1 z^{-1})$ term and separated the terms in $d_1 z^{-1}$. The first term in this expression is analytic everywhere inside the unit circle. The second term has a simple pole at z = 0, and by Cauchy's integral formula

$$
\begin{aligned}
-\frac{p^{-j-1}}{2\pi i} d_1 \oint \frac{zG(z)-p^{-1}G(p^{-1})}{z(1-pz)(z-p)}\,dz &= -p^{-j-1}d_1 \left.\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right|_{z=0} \\
&= -p^{-j-1}d_1 \frac{p^{-1}G(p^{-1})}{p} \\
&= -p^{-j-1}d_1 q_0
\end{aligned}
$$

where $q = \frac{p^{-1}G(p^{-1})}{P}$. By summetry, the third term also equals $-p^{-j-1}d_1 q_0$ and as a result, $2H_j = -2p^{-j-1}d_1 q_0$ for j = 0, 1, 2, ... Multiplying by z^j and summing over $j \in [-\infty, \infty]$ results in

$H(z) = \Sigma_{-\infty}^{-1} - d_1 q_0 p^{-1} \Sigma_0^{\infty}$ p-jzj or $H(z) = \Sigma_{-\infty}^{-1} - \frac{d_1 q_0 p^{-1}}{1-p^{-1}z}$ As in Whitman, $\Sigma_{-\infty}^{-1}$ is an unknown function involving only negative powers of z. Using the definition of H(x)

$$hF(z) = \Sigma_{-\infty}^{-1} - (1-d_1 z)(1-d_1 z^{-1})\left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] - \frac{d_1 q_0 p^{-1}}{1-p^{-1}z}$$

Expanding $(1-d_1 z)(1-d_1 z^{-1})$ allows this to be written

$$
\begin{aligned}
hF(z) = \Sigma_{-\infty}^{-1} - (1+d_1^2)\left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] + d_1 z \left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] \\
+ d_1 z^{-1}\left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] - \frac{d_1 q_0 p^{-1}}{1-p^{-1}z} .
\end{aligned}
$$

Since policy at time t may not depend on future shocks $F(z) = [F(z)]_+$ where $[\ ]_+$ is the linear annihilator which means ignore negative powers of z. As in Whiteman (1986), p. 1394) the first term on the right-hand side equals zero when the annihilator is applied, and since $z = p^{-1}$ is not a singularity of the term in brackets the second, third and fifth terms are equal to themselves. The fourth term has a simple pole at $z = 0$. By the lemma in Hansen and Sargent (1981, p. 120)

$$\left\{d_1 z^{-1}\left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right]\right\}_+ = d_1 z^{-1}\left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] - d_1 z^{-1} q_o$$

where $q_o = \frac{p^{-1}G(p^{-1})}{P}$. To see this note that the residue of the term in braces at $z = 0$ is given by

$$\text{(B.3)} \quad \lim_{z\to o}\left[d_1 \frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] = \frac{p^{-1}G(p^{-1})}{p}$$

and thus the principal part of the Laurent expansion of the term in braces at $z = 0$ is $d_1 p^{-1}G(p^{-1})/pz$. The Hansen-Sargent lemma requires subtracting the principal part of the Laurent expansion from the annihiland to obtain the annihilate. This is (B.3).

We can now write

$$\text{(B.4)} \quad hF(z) = -(1-d_1 z)(1-d_1 z^{-1})\left[\frac{zG(z)-p^{-1}G(p^{-1})}{(1-pz)(z-p)}\right] - d_1 z^{-1} q_o - \frac{d_1 q_0 p^{-1}}{1-p^{-1}z}$$

or

$$\text{(B.5)} \quad (1-pz)(z-p)hF(z) = -(1-d_1 z)(1-d_1 z^{-1})[zF(z) + zA(z) - p^{-1}G(p^{-1})]$$
$$- (1-pz)(1-pz^{-1})d_1 q_o - (1-pz)(1-pz^{-1})\frac{d_1 q_0 p^{-1}}{1-p^{-1}z}$$

Notice the last term in (B.5) may be written

$$-pz(1-p^{-1}z^{-1})(-pz^{-1})(1-p^{-1}z) \cdot \frac{d_1 q_0 p^{-1}}{1-p^{-1}z}$$

which equals

$$p^2 (1-p^{-1}z^{-1})d_1 q_0 p^{-1} = (1-p^{-1}z^{-1})d_1 q_0 p = d_1 q_0 p - z^{-1}d_1 q_0$$

Thus, expanding the right-hand side and using the definition of q_o, (B.5) may be written

$$zg(1-mz)(1-mz^{-1})F(z) = -(1-d_1 z)(1-d_1 z^{-1})zA(z)$$
$$+ [(1+d_1^2)\, p^{-1}G(p^{-1}) - (1+p^2)d_1 q_o - d_1 q_0 p] + z^{-1}d_1 q_0$$

where

(B.6) $g(1-mz)(1-mz^{-1}) = [(1-pz)(1-pz^{-1})h + (1-d_1 z)(1-d_1 z^{-1})]$.

From (B.6)

$$h + hp^2 + 1 + d_1^2 = g(1+m^2) \text{ and } hp + d_1 = gm$$

which implies

$$\frac{h + hp^2 + 1 + d_1^2}{hp + d_1} = m + m^{-1}$$

which implies $|m| < 1$. Thus, we can write (B.5) as

(B.7) $g(1-mz)F(z) = -(1-mz^{-1})^{-1}D(z)$
$$+ (1-mz^{-1})^{-1}z^{-1}[(1+d_1^2)p^{-1}G(p^{-1})-(1+p^2)d_1 q_o - d_1 q_0 p$$
$$+ (1-mz^{-1})^{-1}\, z^{-2}d_1 q_0]_+$$

where $D(z) = (1-d_1 z)(1-d_1 z^{-1})A(z)$. Now apply the linear annihilator operator $[\ ]_+$ to both sides of (B.7) noting that the left hand side function contains no negative powers of z. So

$$g(1-mz)F(z) = -[(1-mz^{-1})^{-1}D(z)]_+ +[(1-mz^{-1})^{-1}z^{-1}\{(1+d_1^2)p^{-1}G(p^{-1})-(1+p^2)d_1 q_o$$
$$-d_1 q_0 p\} + (1-mz^{-1})^{-1}\, z^{-2}d_1 q_0]_+$$

The last term vanishes as it involves only negative powers of z. Therefore the z-transform of F(L) is given by

$$F(z) = -g^{-1}(1-mz)^{-1}[(1-mz^{-1})^{-1}D(z)]_{+}.$$

Again, by the lemma in Hansen and Sargent (1980, p. 120)

$$[(1-mz^{-1})^{-1}D(z)]_{+} = -m^{-1}\frac{zD(z) - mD(m)}{1 - m^{-1}z}.$$

Noting that $gm = (hp + d_1)$ completes the proof.

Appendix C

DATA**

The data used for estimating the Maine potato model is given in the following table. The soil management measure is given by the formula SM=1/(1-PO) where PO is the percentage of total acreage of oats and potatoes planted in oats. This gives a measure of soil management on a scale from 0 to infinity. The suggested rotation is oats, potatoes, yearly, thus the "goal" value of SM is 2 (PO=0.5). It is a goad measure for soil management because the P factor in the USLE has remained essentially constant over the period of the data (see Healer, et al, 1985). Over the data period, the primary force determining the C factor has been crop rotation, and thus SM should be closely correlated with overall soil management.

Nonsoil inputs (INPUTS) is a composite measure of purchased and nonpurchased farm inputs for the Northeast. Soil depth (SOLID) was estimated using the USLE. See Lawrence for details. The relative price of inputs (INPRI) is the ratio of an index of prices paid by farmers in the Northeast and potato prices far the state of Maine. Finally, the government

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** I would like to thank Doug Lawrence for providing the data used in this analysis. For a complete description see Lawrence (1987).

subsidy, ACP, is the ratio of ACP cost sharing per acre for the state of Maine to the price of potatoes. All nominal dollars were adjusted to 1967 values using the Consumer Price Index.

ENTRY	INPUTS	SM	SOILD	ACP	INPRI
1950:	146.000	1.70455	11.5700	.503015	190.698
1951:	145.000	2.31000	11.5540	.207164	90.099
1952:	143.000	1.66667	11.5460	.280420	126.267
1953:	141.000	1.71429	11.5300	.756113	345.946
1954:	138.000	1.75000	11.5150	.254707	118.605
1955:	135.000	1.69504	11.5000	.319126	141.808
1956:	133.000	1.61905	11.4840	.461838	206.612
1957:	128.000	1.75912	11.4670	.247033	119.535
1958:	126.000	1.57823	11.4530	.489282	237.838
1959:	124.000	1.63121	11.4340	.232384	114.655
1960:	121.000	1.48299	11.4170	.408122	194.853
1961:	119.000	1.38095	11.3860	.518767	235.398
1962:	117.000	1.41781	11.3570	.463293	221.311
1963:	115.000	1.42336	11.3310	.305567	141.451
1964:	112.000	1.38571	11.3050	.149953	70.130
1965:	110.000	1.35099	11.2760	.228481	117.373
1966:	108.000	1.26582	11.2430	.317647	170.000
1967:	107.000	1.23602	11.2050	.395359	213.235
1968:	104.000	1.25161	11.1580	.289774	156.757
1969:	102.000	1.25466	11.1150	.229523	137.273
1970:	102.000	1.30719	11.0720	.257576	158.081
1971:	100.000	1.31034	11.0350	.309598	192.941
1972:	97.0000	1.34074	11.0000	.130710	85.610
1973:	98.0000	1.31884	10.9680	.074270	58.483
1974:	99.0000	1.31690	10.9330	.182556	165.862
1975:	97.0000	1.40164	10.8980	.093760	87.273
1976:	99.0000	1.32759	10.8700	.129870	112.929
1977:	100.000	1.30645	10.8360	.183715	172.321
1978:	103.000	1.38655	10.8000	.161721	162.694
1979:	106.000	1.38793	10.7710	.202580	221.538
1980:	104.000	1.42593	10.7420	.093148	110.207
1981:	102.000	1.46226	10.7160	.146237	190.000
1982:	101.000	1.43925	10.6920	.195774	258.209
1983:	97.0000	1.43750	10.6670	.119135	149.831

References

S. Batie, Policies, institutions and incentives fur soil conservation, in "Soil Conservation Policies, Institutions and Incentives," (Halcrow, et al, eds.), Soil Conservation Society of America, Ankeny, Iowa, (1982).

G. E. P. Box and G. M. Jenkins;, "Time Series Analysis, Forecasting and Control," Holden Day, San Francisco (1970).

D. W. Bromley, The rights of society versus the rights of landowners and operators, in "Soil Conservation Policies, Institutions and Incentives," (Halcrow, et al, eds.), Soil Conservation Society of America, Ankeny, Iowa, (1982).

O. R. Burt, Farm level economics of soil conservation in the Palouse area of the Northwest, American Journal of Agricultural Economics. 63, 83-91. (1981).

K. W. Easter and M. L. Cotner, Evaluation of current soil conservation strategies, in "Soil Conservation Policies, Institutions and Incentives," (H. G. Halcrow, et al, eds.), Soil Conservation Society of America, Ankeny, Iowa (1982).

B. Eleveld and H. G. Halcrow, How much soil conservation is optimal for society?," in "Soil Conservation Policies, Institutions and Incentives," (H. G. Halcrow, et al, eds.), Soil Conservation Society of America, Ankeny, Iowa, (1982).

C. Ervin and D. Ervin, Factors affecting the use of soil conservation practices: hypotheses, evidence and policy implications. Land Economics, 58, 277-292, (1982).

D. L Forster and G. S. Becker, Costs and income effects of alternative erosion control strategies: the Honey Creek watershed, North Central Journal of Agricultural Economics, 1, 53-60, (1979).

J. E. Freund, "Mathematical Statistics," 2nd ed., Prentice-Hall, Englewood Cliffs, N.J. (1971).

R. E. Heimlich and N. Bills, An improved erosion classification for conservation policy, Journal of Soil and Water Conservation, July, 261-266, (1984).

P. R. Hepler, L. H. Long and J. A. Ferwerda, "FARMS" crop yield and quality relationships with soil erosion, 1980., bulletin 799, Maine Agricultural Experiment Station, University of Maine, Orono, Maine (1983).

G. G. Judge, et al, "The Theory and Practice of Econometrics," 2nd ed., Wiley, New York (1985).

D. J. Lawrence, "Resource Use Rates: Estimation of Time Invariant Decision Rules," unpublished PhD dissertation, University of New Hampshire, (1987).

R. E. Lucas, Jr., Econometric Policy Analysis: a critique, in "The Phillips Curve and Labor Markets," (K. Brunner and S. H. Meltzer, eds.), North-Holland, Amsterdam, (1976).

K. E. McConnell, An Economics Model of Soil Conservation, American Journal of Agricultural Economics, 65, 83-89, (1983).

I. C. Moore, et al, Financial incentives to control agricultural nonpoint-source pollution, Journal of Soil and Water Conservation, March, 60-64, (1979).

T. L. Napier and D. L. Forster, Farmer attitude and behavior associated with soil erosion control, in "Soil Conservation Policies Institutions and Incentives, (Halcrow, et al eds.), Soil Conservation Society of America, Ankeny, Iowa, (1982).

T. L. Napier, et al, Factors affecting adoption Of conventional and conservation tillage practices in Ohio, Journal of Soil and Water Conservation May, 205-209, (1984).

T. Prato, Allocation of federal assistance to soil conservation, Land Economics, 63:2, 193-200, (1987).

W. D. Rasmussen, History of soil conservation, institutions and incentives, in "Soil Conservation Policies, Institutions and Incentives," (H. G. Halcorw, et al, eds.), Soil Conservation Society of America, Ankeny, Iowa, (1982).

R. E. Rosenman, Sail management, productivity and expectations, mimeo, Washington State University, (1986).

B. Saliba and D. Bromley, Empirical analysis of the relationship between soil conservation and farmland characterictics, selected paper, AAEA meetings, Ithaca, New York, (1984).

J. S. Shortle and J. A. Miranowski, Intertemporal soil resource use: is it socially excessive?, Journal of Environmental Economics and Management, 14, 99-111, (1987).

C. H. Whiteman, "Linear Rational Expectations Models: A Users Guide," University of Minnesota Press, Minneapolis, (1983).

C. H. Whiteman, Analyticalpolicy design under rational expectations, Econometrica, 6, 1387-1405, (1986).

W. H. Wischmeier and D. D. Smith, "Predicting Rainfall Erosion Losses: A Guide to Conservation Planning," USDA Agricultural Handbook No. 537, (1978).

Table 1: INPUTS

DEPENDENT VARIABLE 13 INPUTS
FROM 1952: 1 UNTIL 1983: 1
OBSERVATIONS 32 DEGREES OF FREEDOM 28
R**2 .92101723 RBAR**2 .91255479
SSR 506.71397 SEE 4.2540484
DURBIN-WATSON 1.40246133
Q(15)= 9.00915 SIGNIFICANCE LEVEL .877039

LABEL	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
*****	***	***	************	************	************
CONSTANT	0	0	-235.1898	33.06478	-7.113000
SM	14	1	35.33967	4.366006	8.094280
SOILD	4	0	26.11780	3.286415	7.947202
INPRI	15	1	.2719733E-01	.1235583E-01	2.201174

Table 2A: SOIL MANAGEMENT

DEPENDENT VARIABLE 14 SM
FROM 1952: 1 UNTIL 1982: 1
OBSERVATIONS 31 DEGREES OF FREEDOM 27
R**2 .82716479 RBAR**2 .80796087
SSR .12934168 SEE .69212951E-01
DURBIN-WATSON .87587781
Q(15)= 23.3652 SIGNIFICANCE LEVEL .766883E-01

LABEL	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
*******	***	***	************	************	************
CONSTANT	0	0	3.219786	.9043187	3.560455
SOILD	4	-1	-.3149353	.9673736E-01	-3.255571
INPUTS	13	-1	.1515624E-01	.1841353E-02	8.231038
ACP	16	1	.1498358	.1091318	1.372980

Table 2B: SOIL MANAGEMENT (CORRECTED FOR SERIAL CORRELATION)

DEPENDENT VARIABLE 14 SM
FROM 1953: 1 UNTIL 1982: 1
OBSERVATIONS 30 DEGREES OF FREEDOM 26
R**2 .87709435 RBAR**2 .86291293
SSR .85368105E-01 SEE .57300861E-01
DURBIN-WATSON 1.74190968
Q(15)= 9.51948 SIGNIFICANCE LEVEL .848829

LABEL	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
*******	***	***	************	************	************
CONSTANT	0	0	3.325983	1.328401	2.503750
SOILD	4	-1	-.3311274	.1453958	-2.277420
INPUTS	13	-1	.1585510E-01	.3394528E-02	4.670782
ACP	16	1	.1765368	.8125106E-01	2.172733

LABEL	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
*******	***	***	************	************	************
RHO	1	0	.5348958	.1788211	2.991235

Table 3A: SOIL DEPTH

```
DEPENDENT VARIABLE     4      SOILD
FROM  1952:  1  UNTIL  1983:  1
OBSERVATIONS              32      DEGREES OF FREEDOM      30
R**2               .99973054      RBAR**2            .99972156
SSR            .70685309E-03      SEE            .48540467E-02
DURBIN-WATSON .96092942
Q(  15)=    31.4270       SIGNIFICANCE LEVEL  .769810E-02
LABEL      VAR  LAG    COEFFICIENT    STAND. ERROR    T-STATISTIC
*******    ***  ***   ************   ************    ************
SOILD       4    1   .9917293       .5803566E-03   1708.828
SM         14    1   .4417327E-01   .4379082E-02   10.08734
```

Table 3B: SOIL DEPTH (CORRECTED FOR SERIAL CORRELATION)

```
DEPENDENT VARIABLE     4      SOILD
FROM  1953:  1  UNTIL  1983:  1
OBSERVATIONS              31      DEGREES OF FREEDOM      29
R**2               .99990025      RBAR**2            .99989681
SSR            .24531739E-03      SEE            .29084739E-02
DURBIN-WATSON 1.24954366
Q(  15)=    13.3688       SIGNIFICANCE LEVEL  .573832
LABEL      VAR  LAG    COEFFICIENT    STAND. ERROR    T-STATISTIC
*******    ***  ***   ************   ************    ************
SOILD       4    1   .9891213       .5201961E-03   1901.439
SM         14    1   .6475179E-01   .4027611E-02   16.07697

LABEL      VAR  LAG    COEFFICIENT    STAND. ERROR    T-STATISTIC
*******    ***  ***   ************   ************    ************
RHO         1    0   .3513353E-01   .8421299E-01   .4171985
```

Table 4: ACP (ACTUAL SUBSIDY RULE)

DEPENDENT VARIABLE 16 ACP
FROM 1952: 1 UNTIL 1983: 1
OBSERVATIONS 32 DEGREES OF FREEDOM 21
R**2 .96456216 RBAR**2 .94768699
SSR .24734960E-01 SEE .34319896E-01
DURBIN-WATSON 1.96013797
Q(15)= 10.5517 SIGNIFICANCE LEVEL .783682

LABEL	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
*******	***	***	************	************	************
CONSTANT	0	0	-5.072464	1.313992	-3.860347
ACP	16	1	-.3611584	.2268784	-1.591859
ACP	16	2	-.2394822E-01	.5874922E-01	-.4076347
INPUTS	13	0	.1955010E-03	.4669734E-02	.4186556E-01
INPUTS	13	1	.8150669E-03	.5308226E-02	.1535479
SM	14	0	-.8802489E-01	.1443231	-.6099154
SM	14	1	-.1019312	.8994309E-01	-1.133285
SOILD	4	0	-.3932119	1.895465	-.2074488
SOILD	4	1	.8618584	1.905858	.4522156
INPRI	15	0	.1650003E-02	.1406665E-03	11.72989
INPRI	15	1	.5775978E-03	.4290431E-03	1.346247

Table 5A: ACP (CONSISTENT RULE)

```
DEPENDENT VARIABLE    16      ACP
FROM  1952:  1  UNTIL  1983:  1
OBSERVATIONS               32      DEGREES OF FREEDOM     29
R**2              -.20386554      RBAR**2          -.28689075
SSR           .84027592           SEE           .17022054
DURBIN-WATSON 1.49400504
Q(  15)=   30.5949         SIGNIFICANCE LEVEL  .994831E-02
LABEL      VAR  LAG    COEFFICIENT   STAND. ERROR    T-STATISTIC
*******    ***  ***    ************   ************   ************
CONSTANT    0    0   -.9885730        .4736505       -2.087136
ACP        16    1   -.3280431E-01    .2590371       -.1266395
SM         14    0    .8808595        .3558537        2.475341
```

Table 5B: ACP (CONSISTENT RULE ADJUSTED FOR SERIAL CORRELATION)

```
DEPENDENT VARIABLE    16      ACP
FROM  1953:  1  UNTIL  1983:  1
OBSERVATIONS               31      DEGREES OF FREEDOM     28
R**2               .20761079      RBAR**2            .15101156
SSR           .55297775           SEE           .14053187
DURBIN-WATSON 1.72396395
Q(  15)=   10.2734         SIGNIFICANCE LEVEL  .802196
LABEL      VAR  LAG    COEFFICIENT   STAND. ERROR    T-STATISTIC
*******    ***  ***    ************   ************   ************
CONSTANT    0    0   -.1536950        .1936818       -.7935442
ACP        16    1    .5062937        .2237805        2.262457
SM         14    0    .1990600        .1529790        1.301224

LABEL      VAR  LAG    COEFFICIENT   STAND. ERROR    T-STATISTIC
*******    ***  ***    ************   ************   ************
RHO         1    0   -.3310390        .2403910       -1.377086
```